Hiroshi KANDA* & Kunito NEHIRA**: **The spore germination and the protonema development in some species of the Hypnobryales** (Musci)

神田啓史*・根平邦人**：蘚類シトネゴケ目数種の胞子発芽と原糸体形成

Although considerable attentions have been paid to developmental study of mosses, we have little information for the sporeling in pleurocarpous mosses. In the present paper, the protonema of 18 species belonging to 6 families of the Hypnobryales of the pleurocarpous mosses are studied.

Table 1 shows the materials treated with their localities and dates of the collections. Of 18 species, those with asterisk mark were described in detail.

Spores were sown on the liquid medium of one-half-strength Knop's solution in closed petri dishes (6 cm in diameter) with about 10 ml of medium which was autoclaved before the experiment. The pH of the medium was adjusted to 5.8. The cultures were kept in an incubator at 22°C-24°C under about 1000 lux on continuous light from white fluorescent tubes.

Observations

1. *Anacamptodon latidens* (Besch.) Broth. (Fig. 1, A-G)

Spores are spherical, 17.5-18.0 μ in diameter and papillose on surface (Fig. 1, A). In a few days after treatment, the spore becomes ovoid. The first wall is formed crossing the long axis of ovoid cell at right angle. One of daughter cells elongates into short filament, and the second wall is formed in parallel to the first wall, resulting in a three-celled filamentous protonema (Fig. 1, B). By further divisions, a long filamentous protonema with short branches is developed (Fig. 1, C). One or two branches are usually

---

* Department of Biological Data, Division of Collection and Processing, National Institute of Polar Research, Tokyo 173. 国立極地研究所資料系生物部門.

** Department of Biology, Faculty of Integrated Arts & Sciences, Hiroshima University, Hiroshima 730. 広島大学総合科学部生物学教室.

Table 1. Materials and their localities.

Species	Locality	Date of Collection (Date of Experiment)
Fabroniaceae		
*_Anacamptodon latidens_	Ozegahara Moor	Aug. 1973 (Mar. 1974)
Leskeaceae		
*_Lescuraea saxicola_	Mt. Rishiridake	Jul. 1973 (Mar. 1974)
Thuidiaceae		
*_Thuidium bipinnatulum_	Ozegahara Moor	Aug. 1973 (Mar. 1974)
Amblystegiaceae		
Cratoneuron filicinum	Mt. Daisetsuzan	Jul. 1973 (Feb. 1974)
Sanionia uncinata	Mt. Ontakesan	Aug. 1973 (Feb. 1974)
Campylium sommerfeltii	Mt. Daisetsuzan	Jul. 1973 (Feb. 1974)
*_Leptodictyum riparium_	Mt. Hakusan	Aug. 1973 (Feb. 1974)
Hygrohypnum tsurugizanicum	Mt. Naebasan	Aug. 1973 (Feb. 1974)
Plagiotheciaceae		
Isopterygium albescens	Amamiooshima Isl.	Mar. 1964 (Apr. 1964)
Vesicularia reticulata	Amamiooshima Isl.	Mar. 1964 (Apr. 1964)
*_Plagiothecium denticulatum_	Mt. Hakkodasan	Aug. 1973 (Mar. 1974)
Herzogiella turfacea	Mt. Rishiridake	Jul. 1974 (Mar. 1974)
Hypnaceae		
Callicladium haldanianum	Mt. Rishiridake	Jul. 1973 (Mar. 1974)
*_Hypnum lindbergii_	Mt. Daisetsuzan	Jul. 1973 (Mar. 1974)
Homomallium connexum	Izumotaisha	May 1964 (May 1964)
Ectropothecium planum	Tokunoshima Isl.	Mar. 1964 (Apr. 1964)
Brotherella recurvans	Shigakogen Plateau	Aug. 1965 (Sep. 1965)
Heterophyllium foliolatum	Mt. Kisokomagatake	Aug. 1973 (Mar. 1974)

protruded from a cell of protonema. The branching may occur from every cell of filamentous protonema (Fig. 1, D). Thus, at the earlier stage the protonema is composed of some elongated filaments and short branches developing from the filament (Fig. 1, F). The short branches are usually composed of 6-10 cells and some secondary branches may develop from the short branches (Fig. 1, E). The bud of leafy plant is formed at earlier stage and usually occurs near the base of the protonema (Fig. 1, G). Later, the brownish, prostrate protonema (caulonema), having numerous elongated

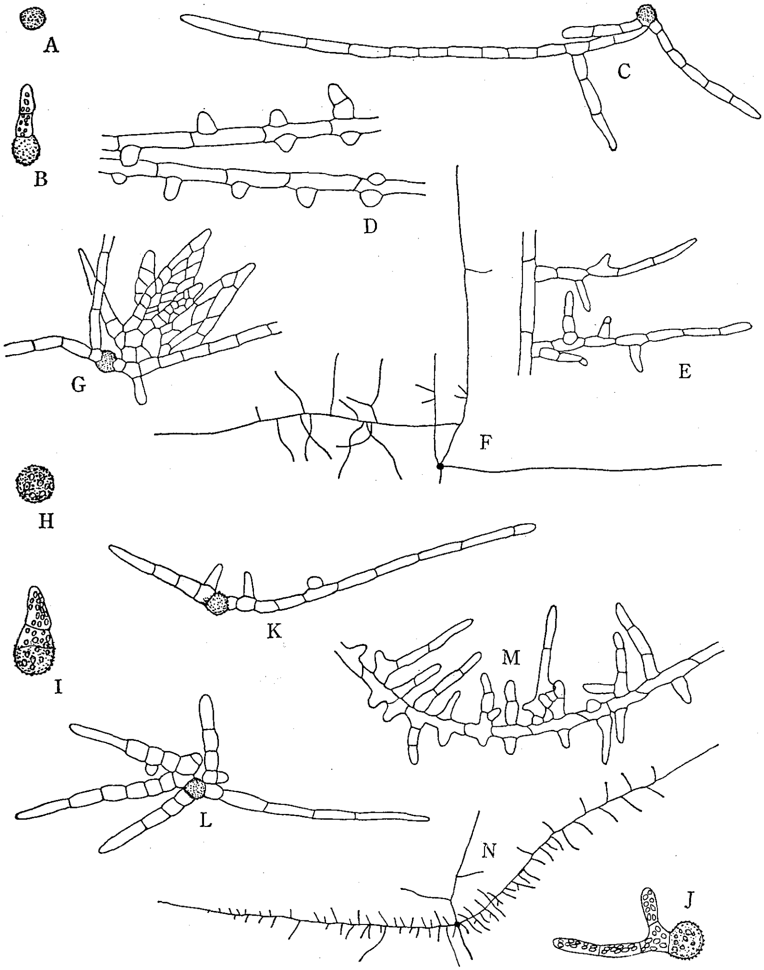

Fig. 1. Various stages of the protonema development in Hypnobryales. A-G. *Anacamptodon latidens* (A, spore; B,C, filamentous protonemata at the earlier stage; D, a part of protonema; E, rhizoids; F, protonema; G, a leafy shoot near primary spore). H-N. *Lescuraea saxicola* (H, spore; I,J, protonemata at the earlier stage; K,L, filamentous protonemata; M, a part of pinnate protonema; N, protonema). A,B,D,E,H-J ×206; C,G,K-M ×124; F ×20; N ×30.

chloroplasts and the oblique septa, is developed, which is clearly distinguished from the greenish erect protonema (chloronema), having numerous globular chloroplasts and the septa crossing the long axis at right angle. This observation indicates that *Anacamptodon latidens* shows the heterotrichous habit.

2. *Lescuraea saxicola* (B.S.G.) Mol. (Fig. 1, H-N; Fig. 2)

Spores are spherical, 15.0-20.0 μ in diameter and papillose on surface. In a few days after treatment, the spore slightly elongates (Fig. 1, H) and becomes ovoid. The first wall is formed crossing the axis of the ovoid spore at right angle. The second wall is transversely formed in one of the daughter cells, resulting in a three-celled protonema (Fig. 1, I). By further divisions, the filamentous protonemata semetimes with branches are developed radially (Fig. 1, J-L). The protonema cells, whose walls are comparatively thick, are short and contain numerous dark-green chloroplasts. At the basal part of protonema, each cell is almost equal both in length and width. The number of branches increases as the protonema developed, forming pinnate protonema (Fig. 1, M, N; Fig. 2). The pinnate system of protonema is the most important feature for this species. *Lescuraea saxicola* does not show the heterotrichous habit.

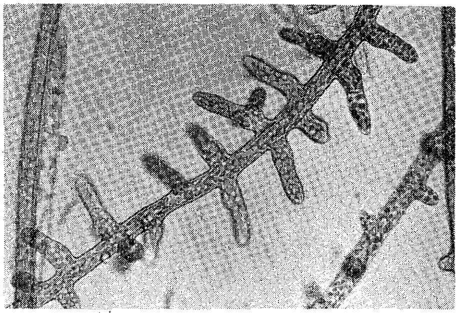

Fig. 2. Pinnate protonema of *Lescuraea saxicola*. ×210.

3. *Thuidium bipinnatulum* Mitt. (Fig. 3, A-F)

Spores are spherical, 12.5-17.5 μ in diameter and papillose on surface (Fig. 3, A). In a few days after treatment, the spore is slightly elongated and becomes ovoid. The first wall is formed crossing the long axis of the ovoid cell at right angle (Fig. 3, B). In one of daughter cells, the second

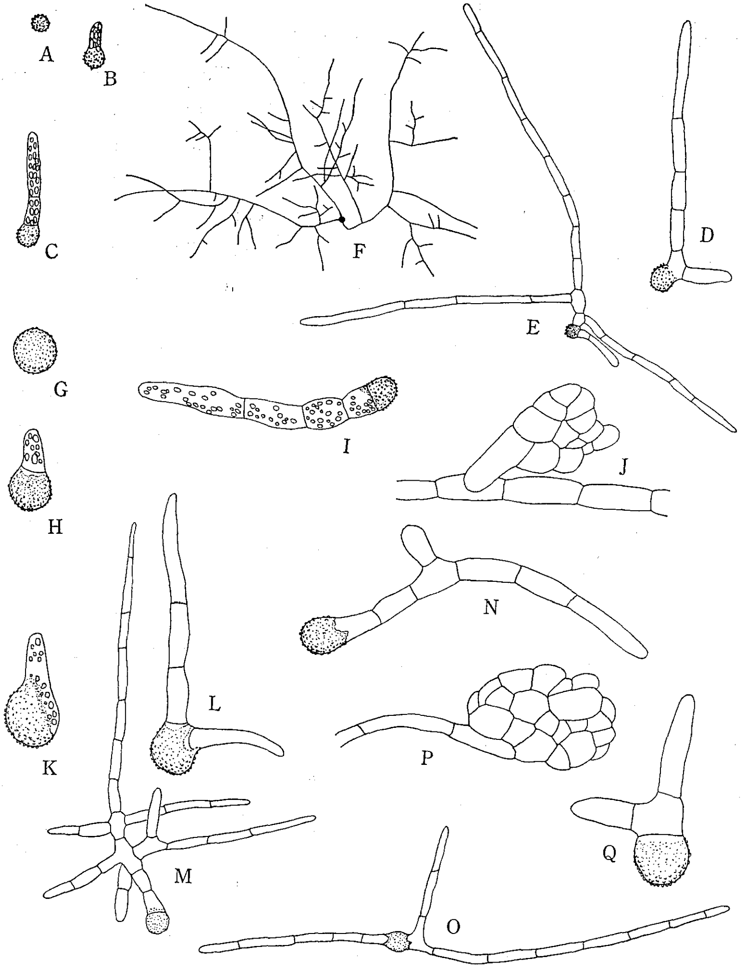

Fig. 3. Various stages of the protonema development in Hypnobryales. A-F. *Thuidium bipinnatulum* (A, spore; B-E, protonema development at the earlier stage; F. protonema). G-J. *Leptodictyum riparium* (G, spore; H, two-celled protonema; I, filamentous protonema; J, a leafy shoot). K-M. *Cratoneuron filicinum* (K, appearance of germ tube-like cell; L,M, filamentous protonemata). N. *Drepanocladus uncinatus* (protonema). O,P. *Campylium sommerfeltii* (O, filamentous protonema; P, bud formation at the apical part of protonema). Q. *Hygrohypnum tsurugizanicum* (protonema).
A-D,G-L,N,P,Q ×206; E,M,O ×124; F ×30.

wall is formed in parallel to the first wall, resulting in a three-celled filamentous protonema (Fig. 3, C). By further divisions, a several-celled filamentous protonema is developed (Fig. 3, D). The number of branches increases as the protonema developed even at the earlier stage (Fig. 3, E, F). Ovoid or globose cells are sometimes formed near the basal and on the apical parts of the protonema. The cells of intercalary part of the protonema turn into brown color. Erect greenish branches are usually formed from the brownish prostrate protonema. *Thuidium bipinnatulum* has no oblique septa in any portion of the protonema, and it does not show the heterotrichous habit.

4. *Leptodictyum riparium* (Hedw.) Warnst. (Fig. 3, G-J)

Spores are spherical, 12.5-15.5 μ in diameter and papillose on surface (Fig. 3, G). In a few days after treatment, the spore becomes ovoid. The first wall is formed crossing the long axis of the ovoid cell (Fig. 3, H). One of daughter cells elongates into short filament and the second wall is formed in parallel to the first wall, resulting in a three-celled filamentous protonema. By further transversal divisions, a long filamentous protonema is developed (Fig. 3, I). There are observed no differences between the filamentous protonema and the branches of the protonema in the cell feature. The branching of protonema is rather poor. The present species has no oblique septa in any portion of the protonema, and it does not show the heterotrichous habit.

Cratoneuron filicinum (Fig. 3, K-M), *Sanionia uncinata* (=*Drepanocladus uncinatus*) (Fig. 3, N), *Campylium sommerfeltii* (Fig. 3, O, P) and *Hygrohypnum tsurugizanicum* (Fig. 3, Q) of the Amblystegiaceae are almost similar to *Leptodictyum riparium* in the protonema development. But in *Campylium sommerfeltii*, it is the most important character that the bud of leafy plant sometimes occurs at the apical part of the protonema (Fig. 3, P).

5. *Plagiothecium denticulatum* (Hedw.) B.S.G. (Fig. 4, A-D)

Spores are spherical, 12.5-17.5 μ in diameter and papillose on surface (Fig. 4, A). In a few days after treatment, the spore becomes ovoid. The first wall is formed crossing the long axis of the ovoid cell (Fig. 4, B). One of daughter cells elongates into the short filament, and the second wall is formed in parallel to the first wall, resulting in a three-celled filamentous protonema (Fig. 4, C). By further divisions, a long filamentous

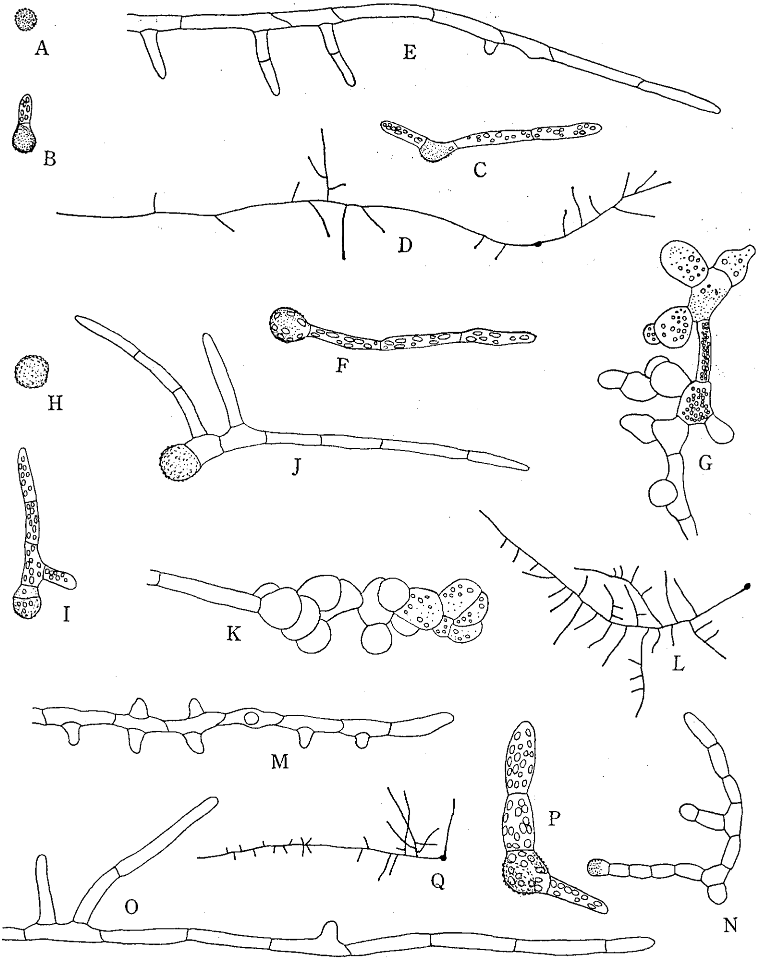

Fig. 4. Various stages of the protonema development in Hypnobryales.
A-D. *Plagiothecium denticulata* (A, spore; B,C, protonemata at the earlier stage; D, protonema). E. *Isopterygium albescens* (an apical part of protonema). F. *Vesicularia reticulata* (filamentous protonema). G. *Herzogiella turfacea* (ovoid or globose cells of protonema). H-L. *Hypnum lindbergii* (H, spore; I,J, protonemata at the earlier stage; K, ovoid or globose cells of protonema). M. *Callicladium haldanianum* (an apical part of protonema). N. *Homomallium connexum* (protonema). O. *Ectropothecium planum* (an apical part of protonema). P. *Brotherella recurvans* (protonema at the earlier stage). Q. *Heterophyllium foliolatum* (protonema).
A-C,E,G-K,M ×206; D,L,Q ×30; F,P ×390; N,O ×195.

protonema is developed. Since the protonema cells are considerably flexible, the filament is usually twisted. No differences are observed between the filamentous protonema and the branches of the protonema in the cell feature. The branching of protonema is rather poor (Fig. 4, D). Ovoid or globose cells are sometimes formed at the apical part of the protonema, which are also observed in some pleurocarpous mosses such as *Herzogiella turfacea* (Fig. 4, G) and *Hypnum lindbergii* (Fig. 4, K). *Plagiothecium denticulatum* has no oblique septa in any portion of the protonema, and it dose not show heterotrichous habit.

Isopterygium albescens (Fig. 4, E). *Vesicularia reticulata* (Fig. 4, F) and *Herzogiella turfacea* of the Plagiotheciaceae are almost similar to *Plagiothecium denticulatum* in the protonema development.

6. *Hypnum lindbergii* Mitt. (Fig. 4, H-L)

Spores are spherical, 16.0-18.0 μ in diameter and papillose on surface (Fig. 4, H). In a few days after treatment, the spore becomes ovoid. The first wall is formed crossing the long axis of the ovoid cell at right angle. One of daughter cells elongates and the second wall is formed in parallel to the first wall, resulting in a three-celled filamentous protonema. By further transversal divisions, a long filamentous protonema is developed (Fig. 4, I, J). Since the cells of the protonema are considerably flexible, the filament is usually twisted. There are observed no differences between the filamentous protonema and the branches of the protonema in the cell feature. The branching of protonema is rather poor. This species does not show the heterotrichous habit.

For the Hypnaceae, the following species were also observed: *Homomallium connexum* (Fig. 4, N), *Callicladium haldanianum* (Fig. 4, M), *Brotherella recurvans* (Fig. 4, P), *Ectropothecium planum* (Fig. 4, O) and *Heterophyllium foliolatum* (Fig. 4, Q; Fig. 5). *Homomallium connexum* is shorter in the length of protonema cell than the others in the Hypnaceae (Fig. 4, N). In *Callicladium haldanianum*, the longer filamentous protonema is well developed and the bud of leafy plant usually occurs on the cell of the prostrate protonema. In *Hypnum lindbergii* and *Brotherella recurvans* the clusters of ovoid or globose cells are sometimes formed at the apical part of the protonema (Fig. 4, K). *Ectropothecium planum* (Fig. 4, O) and *Heterophyllium foliolatum* (Fig. 4, Q; Fig. 5) are almost the same as *Hypnum lindbergii* in the proto-

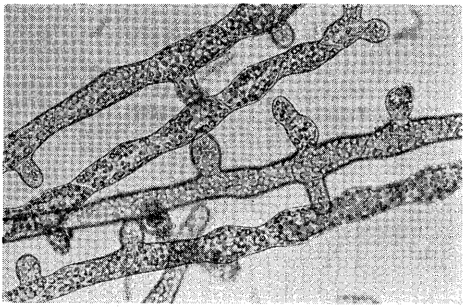

Fig. 5, Protonema cells of *Heterophyllium foliolatum*. ×210.

nema development.

Discussions

For the Leskeaceae, protonema of *Pseudoleskeopsis orbiculata* (=*P. japonica*) was already observed by Nehira (1964). This species differs from *Lescuraea saxicola* described in the present paper in the protonema structure; the former shows heterotrichous habit, while the latter does not.

For the Thuidiaceae, protonemata of *Haplocladium capillatum* and *Claopodium assurgens* were already observed by Noguchi & Miyata (1957) and by Nehira (1965), respectively. *Thuidium bipinnatulum* is almost the same with those species in the protonema development.

As to the sporelings in other families of the Hypnobryales, two reports for Brachytheciaceae were already published by Allsopp & Mitra (1958) on *Eurhyncium riparioides* and *Brachythecium rutabulum* and by Nishida (1966) on *Brachythecium rutabulum*. For the Sematophyllaceae, Nehira (1965) already observed the protonema on *Trichosteleum aculeatum*. These species did not show the heterotrichous habit. It is well known that acrocarpous mosses show the heterotrichous habit in the process of protonema development. But, as mentioned above, in most species of pleurocarpous mosses, the protonema did not show the heterotrichous habit.

The buds of leafy plant are usually formed on the terminal or on the middle part of a prostrate protonema, and the branches of protonema are usually irregular and short. In *Anacamptodon latidens*, the buds of leafy plant usually occur near the basal part of the protonema, and in *Lescuraea*

saxicola, the branches are rather short and numerous in number, forming pinnate system of protonema.

Literature cited

Allsopp, A. & Mitra, G.C. 1958. The morphology of protonema and bud formation in Bryales. Ann. Bot. **22**: 95-115. Nehira, K, 1964. The germination of spores in Musci 2. Hikobia **4**: 43-51. ——. 1965. The germination of spores in Musci 3. Hikobia **4**: 181-187. Nishida, Y. 1966. Studies on the germination of the spore in some mosses (VI). Rep. Att. Mid. School, Shimane Univ. No. 9: 61-68. Noguchi, A. & Miyata, I. 1957. Sporelings and regenerants in some mosses. Kumamoto J. Sci. B. Sect. 2, **3**: 1-19.

* * * *

蘚類シトネゴケ目18種において，胞子発芽と原糸体の形態観察をおこなった。これらのうち，6科から6種（*Anacamptodon latidens, Lescuraea saxicola, Thuidium bipinnatulum, Leptodictyum riparium, Plagiothecium denticulatum* および *Hypnum lindbergii*）を選び，それぞれの原糸体の発達状態を記載的に述べた。その結果，いわゆる pleurocarpous のグループであるシトネゴケ目においては，数例を除いて原糸体に異質糸状性がみられなかった。異質糸状性がわずかにみられたのは *Anacamptodon latidens* であるが，この種では茎葉体の芽の分化が原糸体の基部付近に生ずる傾向があった。*Lescuraea saxicola* の原糸体の細胞はより短かく，この原糸体は分枝の著しい羽状のものであった。

□遠山富太郎：**杉のきた者** pp. 215 中公新書 419 (1976, I) ¥380。近頃はよく大学教授が停年退職され，在職中に抱いていたいくつかのテーマのどれかについて，多年の研究の結果（それは疑問と結論とになるが）を述べた一書を書くということがある。本書もそれで，島根大農学部教授，以前に京大の演習林におられた。スギへの愛惜とスギの発現と分化，その性質をとりあげた文化史的展開が重なっている。終りから読んだ方がわかりよいと思う。スギ科の各種の衰亡と，逆にスギだけが急速に三紀末から洪積世に出現，発展し，そして登呂遺蹟で多量の発掘をみる。それを割って板にできるという性質があったからで，屋根葺きに使われ，糞尿桶と酒樽になり，浅底の高瀬船の資材として，という風に存外深い文化的意義があるとする。その主張はいささかきついが，一つの主張として読み終るとうなずけるものがある。（前川文夫）